Deeply Trapped Electrons in Imaging Plates and Their Utilization for Extending the Dynamic Range

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IV. 3. Deeply Trapped Electrons in Imaging Plates and Their Utilization for Extending the Dynamic Range

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Introduction

Despite of many excellent characteristics of imaging plates (IPs), unexpected effects have become known, i.e., the phenomena of unerasable and reappering latent images. In our previous study[1)], we obtained the following results: (1) unerasable latent images almost disappeared when the IP was held at a temperature of 120°C for 28 days; (2) ultraviolet light of wavelength around 290 nm promoted the reappearance of photostimulated luminescence (PSL) signals; and (3) the amount of PSL signal reappearance increased in proportion to the irradiation dose. These results indicate that electrons are trapped in deep centers, they can be excited optically by 290 nm ultraviolet light and transferred towards the longer wavelength of around 633 nm, producing F centers and they cause latent images to reappear. The number of deeply trapped electrons will increase in proportion to the irradiation dose. In this study, the absorption spectra of deep centers in an over-irradiated IP were studied in the ultraviolet region. By utilizing deeply trapped electrons, we have attempted to extend the dynamic range of an IP readout under a higher irradiation dose.

Materials and methods

Square pieces were cut from the PSL sheet (type BAS-MS2025: FUJIFILM Co., Ltd.) as samples. The BAS-MS samples were uniformly exposed to 150-kV X-ray beams from an MBR-1520R unit (Hitachi Medico Co.). A fluorescent eraser (IP Erase 3:FUJIFILM Co., Ltd.) was used to erase the IP samples with visible light.

Diffracted ultraviolet light from a deep ultraviolet lamp (UXM500SX: USHIO INC.) was used as a light source for excitation of electrons in deep centers. Figure 1 shows a schematic illustration of the diffracted ultraviolet light irradiation system. In order to obtain an ultraviolet spectral distribution curve, a Si pin photodiode (S1226-18BQ: Hamamatsu Photonics K.K.) was used. The curve was calibrated in wavelength by atomic lines emitted from a mercury (Hg) lamp. The spectral distribution curve obtained over the range from 200 nm to 500 nm is exhibited in Fig. 2. IP samples were irradiated with an X-ray dose of 30 Gy and fully erased with visible light. These were used as the IP samples with unerasable latent images. The IP sample was irradiated with diffracted ultraviolet light for 10 min. Then, it was scanned by an IP reader FLA3000 (FUJIFILM Co., Ltd.) with a He-Ne laser and profiles were readout with 0.1-mm steps to obtain spectrum. These procedures are developed for this study and called measurements of luminescence inducing spectra in the following text. A luminescence inducing spectrum can be obtained by correcting each measured spectrum with the spectral distribution curve shown in Fig. 2. A luminescence inducing spectrum of non-irradiated IP samples was obtained in the same manner.

For obtaining dose-response curves, two types of readout system were used; one was the imaging plate reader, FLA3000 and the other a PSL detection system. When an IP sample irradiated with X-ray doses higher than 100 μGy was read out with the FLA3000, the technique of using color cellophane[2)] was used to avoid saturation of the output currents of a photomultiplier tube (PMT), installed in the IP reader. Using two color cellophanes, red and blue, the upper limit of the measurable dose of the IP reader, is extended to 1 Gy and further extended to 100 Gy by the combinations of three colors, red-red-blue[2)]. The homemade PSL detection system consists of a semi-conductor laser, LDU33-635-4.5 (635 nm, SIGMA KOKI CO., LTD.) and a photon counting detector, H7467 (Hamamatsu Photonics K.K.) and a schematic illustration of the PSL detection system is given in Fig. 3. This system was used to read out deeply trapped electrons by continuously stimulating an IP sample showing unerasable latent images with 635-nm light to the level at which the PSLs can no longer be detected. After irradiation with X-ray doses ranging from 8.07 mGy to 80.7 Gy, IP samples were measured using the FLA3000 with the cellophane technique and fully erased with visible light, then measured again with the FLA3000. They were then read out by the PSL detection system.

Results and discussion

Luminescence inducing spectra from 200 nm to 500 nm of the IP sample irradiated with a 30 Gy dose and one not irradiated are shown in Fig. 4. In the irradiated IP sample, a dominant peak is observed at around 320 nm, followed by two small peaks at around 345 nm and 380 nm. However, no intense peak is seen in the non-irradiated sample. This result indicates that several deep centers were created in the irradiated IP sample in the ultraviolet region.

The level scheme of the PSL material has been reported by Iwabuchi et al[3). However, deep centers are not shown there. In Fig. 5, they are illustrated in the level scheme, presuming that they act as competitive trap centers to the F centers in the PSL material. A model of the excitation of deeply trapped electrons and PSL processes is exhibited in Fig. 5. Deeply trapped electrons are excited optically with a 320-nm ultraviolet light to the conduction band and produced F centers. Electrons trapped by F centers, are then stimulated by a He-Ne laser light of 633 nm and emit PSL of 390 nm.

The dose response curves measured by the FLA3000 using sheets of red-blue and red-red-blue cellophane are shown in Fig. 6. A dotted line demonstrates a linear relationship from 8.07 mGy up to 0.8 Gy. The dose response curves begin to decline above 0.8 Gy, indicating that the F centers become saturated. The dose response curve in the IP samples measured by the FLA3000 after fully erasing with visible light is shown in Fig. 7. The dotted line demonstrates a linear relationship from 8.07 mGy up to 2.4 Gy, after that the curve shows another linear relationship up to 80.7 Gy with a considerably smaller slope. The result of total photon counts read out by the PSL detection system from the IP samples are shown in a log-log expression as a function of the irradiated dose (Gy) in Fig. 8, giving a further two orders of magnitude extended the dynamic range up to 80.7 Gy. The dose response curve shows a linear log-log relationship up to 40 Gy and increases steeply up to 80.7 Gy. The differences between Fig. 7 and Fig. 8, which were obtained from the same IPs by the FLA3000 and the PSL detection system, respectively, are explained by the difference in the two readout systems. The FLA3000 readout system scans a large area of an IP at high speed so that it has insufficient time to read out deeply trapped electrons. In contrast, the PSL detection system can read out them efficiently by continuously stimulating an over-irradiated IP sample with 635-nm light.

Comprehensive results show the possibility of utilizing deeply trapped electrons for extending the dynamic range by stimulating over-irradiated IP samples with 635-nm light. In order to read out deeply trapped electrons more effectively, a method to stimulate them by a light with the proper wavelength, appropriate to the absorption peaks, is necessary.

References

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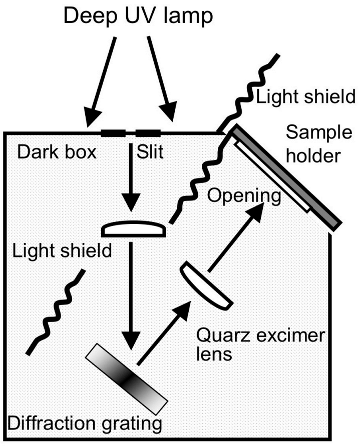

Figure 1. Schematic illustration of the diffracted ultraviolet light irradiation system.

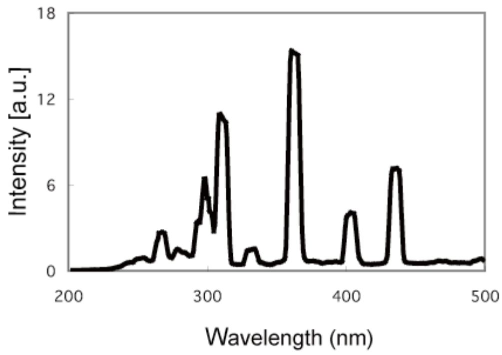

Figure 2. Spectral distribution curve over the range from 200 nm to 500 nm emitted from the diffracted ultraviolet light irradiation system.

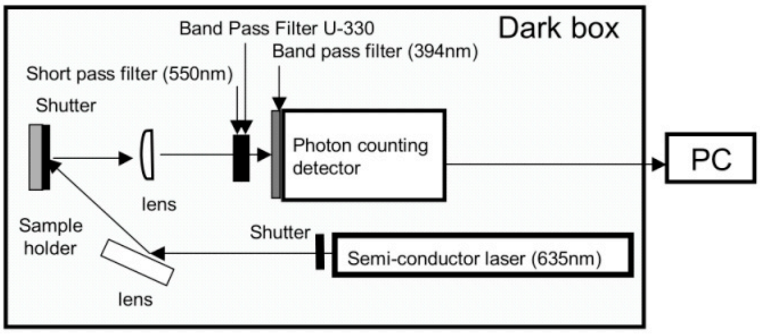

Figure 3. Schematic illustration of the PSL detection system.

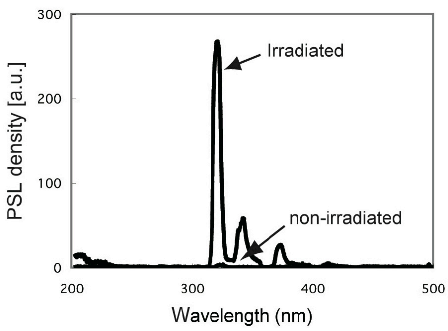

Figure 4. Luminescence inducing spectra from 200 nm to 500 nm of the IP sample irradiated with a 30 Gy dose and one not irradiated.

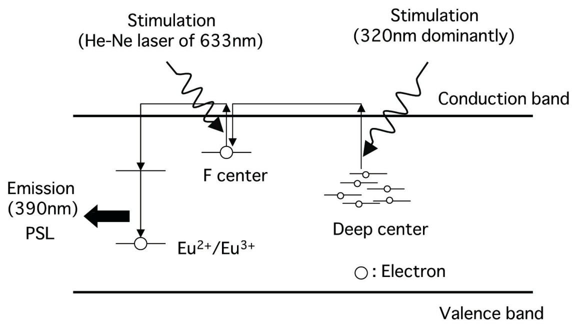

Figure 5. Deep centers are illustrated in the level scheme of the PSL material. A model of the excitation of deeply trapped electrons and PSL processes is also exhibited.

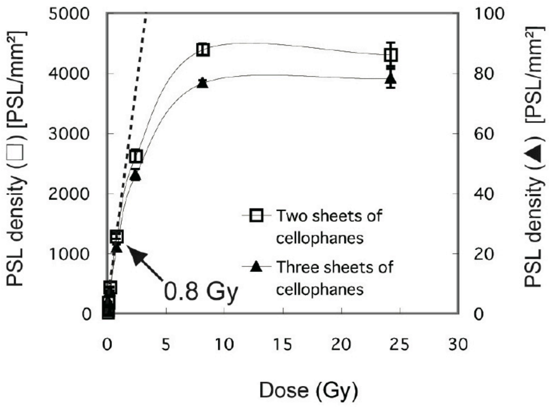

Figure 6. Dose response curves measured by the FLA3000 using sheets of red-blue and red-red-blue cellophane.

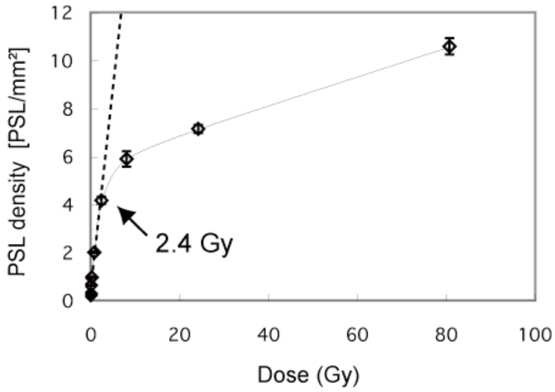

Figure 7. Dose response curve in the IP samples measured by the FLA3000 after fully erasing with visible light.

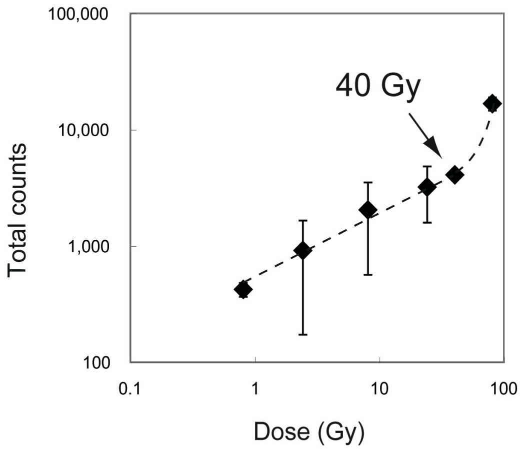

Figure 8. Total photon counts read out by the PSL detection system from the IP samples in a log-log expression as a function of the irradiated dose (Gy). It shows a further two orders of magnitude extended the dynamic range up to 80.7 Gy.